

# **Tsunamis**

## **Chapter 4**

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# Learning Objectives

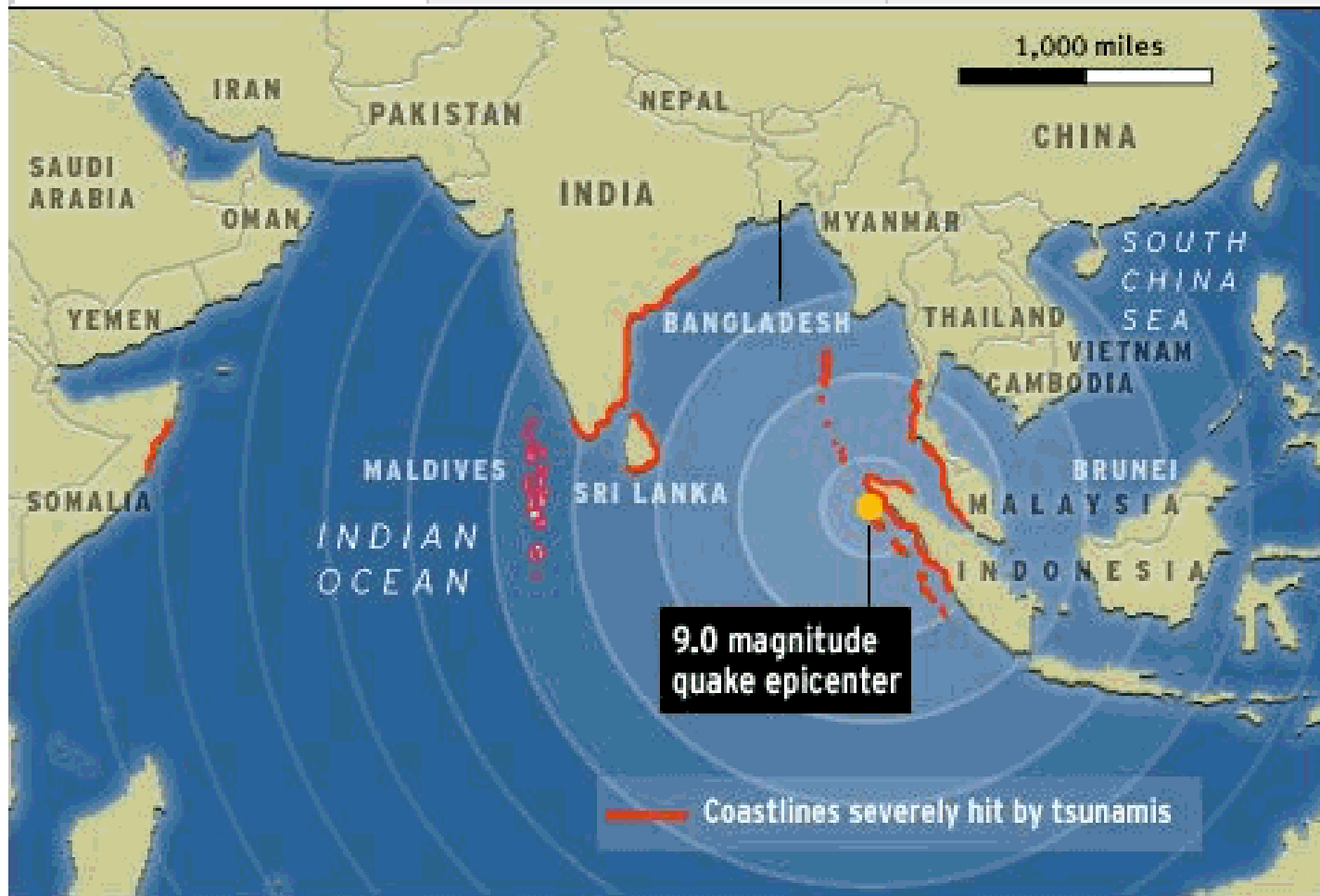
- Understand the process of tsunami formation and development
  - Understand the effects of tsunamis and hazards they pose to coastal regions
  - Know what geographic regions are at risk for tsunamis
  - Recognize the linkages between tsunamis and other natural hazards
  - Know what nations, communities, and individuals can do to minimize the tsunami hazard
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# Past Earthquakes and Tsunamis

- On Dec. 26, 2004, a 9.1 earthquake happened below the Indian Ocean off the west coast of Indonesia
    - The result of that earthquake was a tsunami which caused the most damage ever recorded
      - Close to 230,000 people were killed
      - Hundreds of thousands injured
      - The rupture was about the length of California and the uplift was about 65 ft.
      - There was no tsunami warning system in the Indian Ocean, leading to more people killed and hurt
      - Recognizing the signs of a coming tsunami saved many lives
  - Since this earthquake and tsunami happened a warning system has been installed on the Indian Ocean floor
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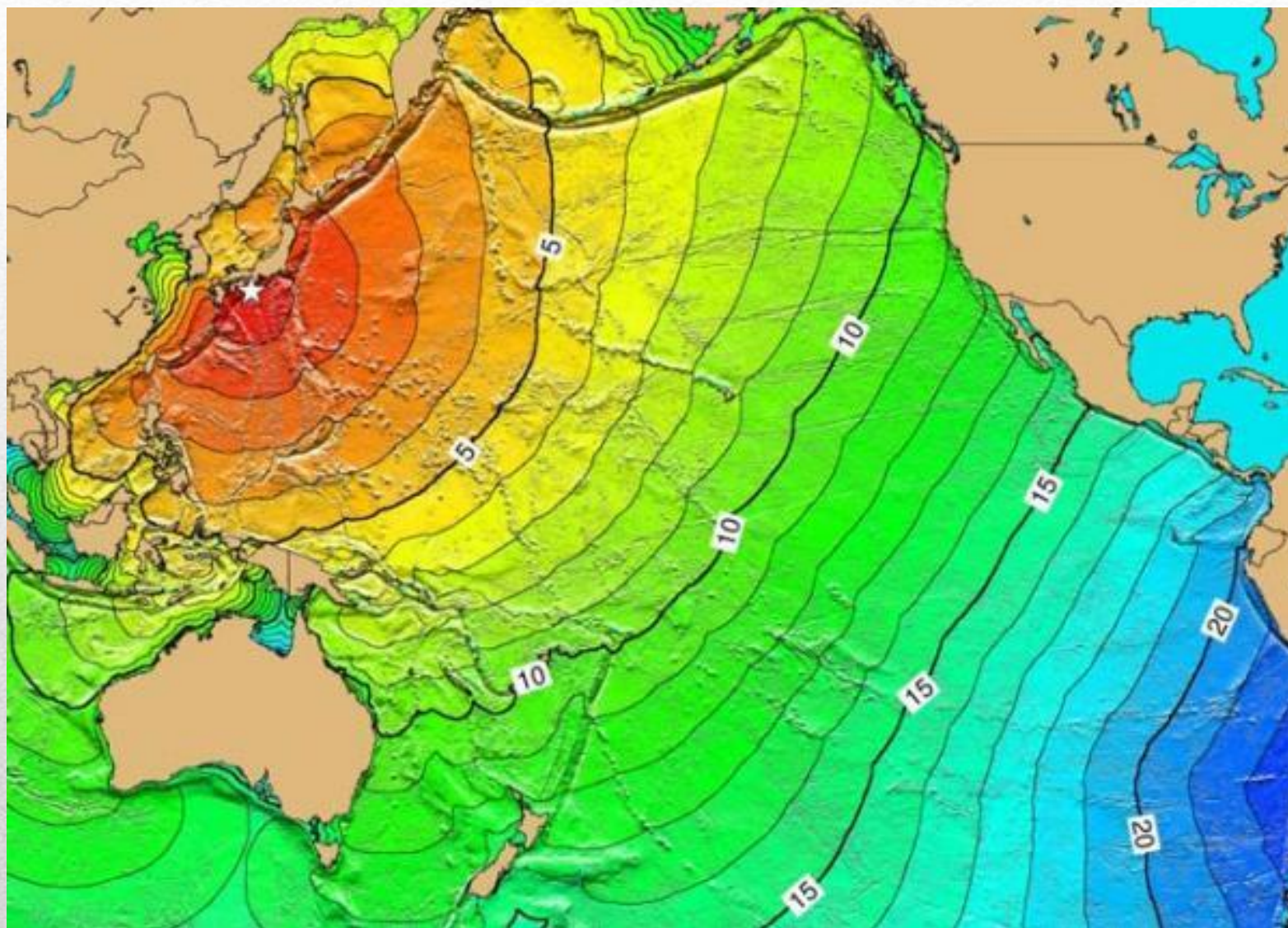
# 2004 Earthquake and Tsunami



# 2011 Japanese Earthquake and Tsunami

- 2011 a 9.0 earthquake happened with a giant tsunami to follow
    - A 6 to 8 meter upthrust happened due to the earthquake
    - This upthrust caused a tsunami that brought destruction along the Pacific Coast of Japan's northern island
    - The tsunami propagated through the Pacific Ocean to North and South America from Alaska to Chile
    - Warnings were issued and many evacuations were carried out in countries along the edge of the Pacific Ocean
    - The worse damage in Japan from the tsunami was the nuclear plant which was inundated with the waves. This cause the plant to be shut down and hoped it wouldn't have a melt down
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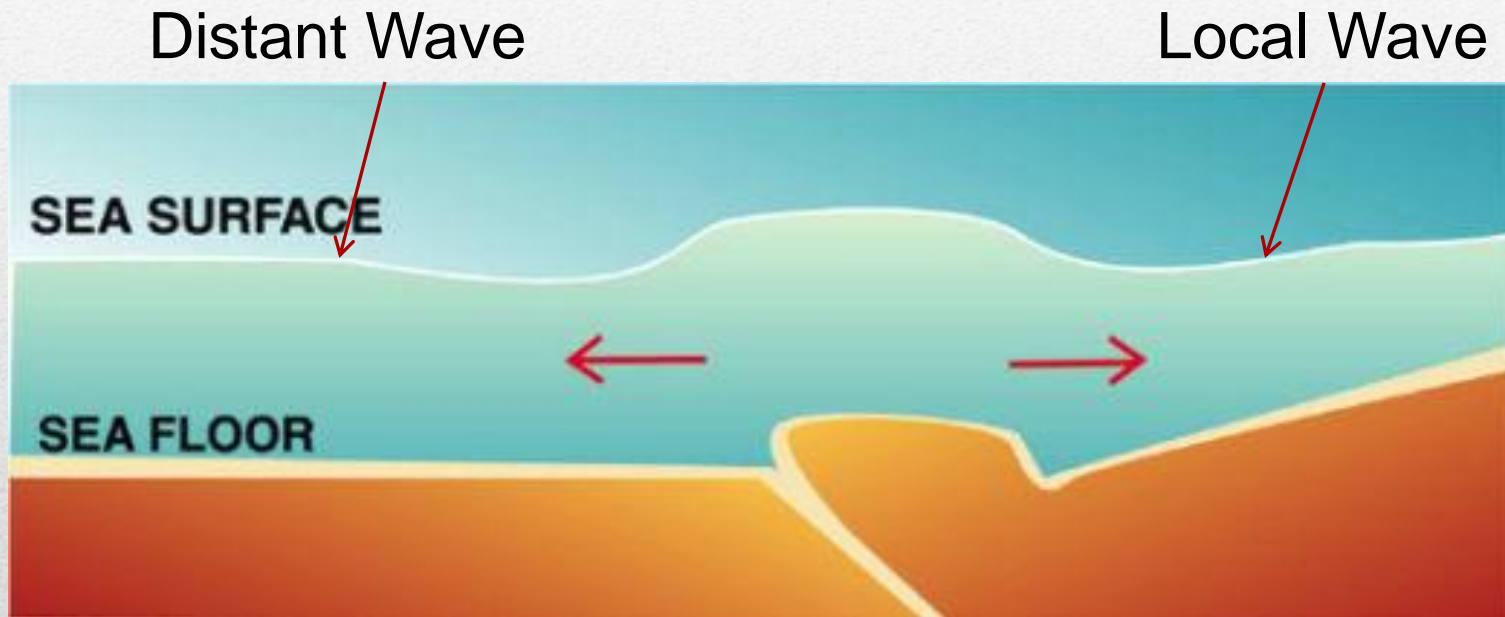


# Tsunami

- Sudden movement of the ocean floor, such as an earthquake, or a landslide
  - Entire water column is disrupted by uplift of ocean floor
  - The uplifted column of water is split in two when it falls to the ocean floor
  - One wave is called the **distant** tsunami, and heads out to sea
  - In deep ocean water the distant waves move very quickly
  - The wave close to shore is called the **local** tsunami and heads to the shore
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# Distant and Local Tsunami Waves



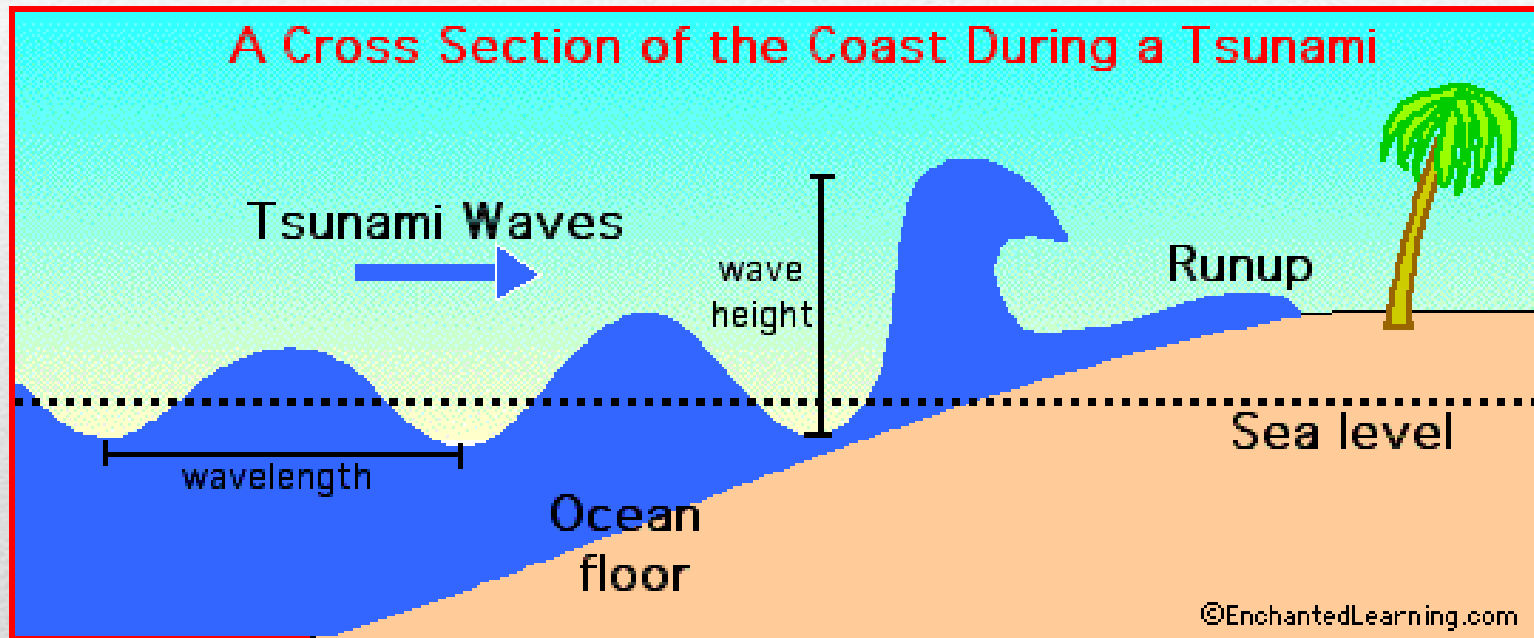


# Tsunami Waves

- When the either kind of waves near the shore their speed decrease
- Nearing the shore line wave length is decreased and the wave height is increased
- Rapid advancing surge of water up to 40 meters high
- This advancing wave is called the **runup** of the wave



# Tsunami Waves





# Landslides and Tsunamis

- How do Landslides cause a Tsunamis?
    - If there is a landslide under that ocean, they can cause a tsunami
    - These landslides are called **submarine landslides**
    - Or they can be large rock **avalanches** that fall from mountains into the ocean
    - In most cases these landslides are caused by earthquakes
    - The earthquake will probably not cause a tsunami, but the displaced water from the landslide could cause a tsunami
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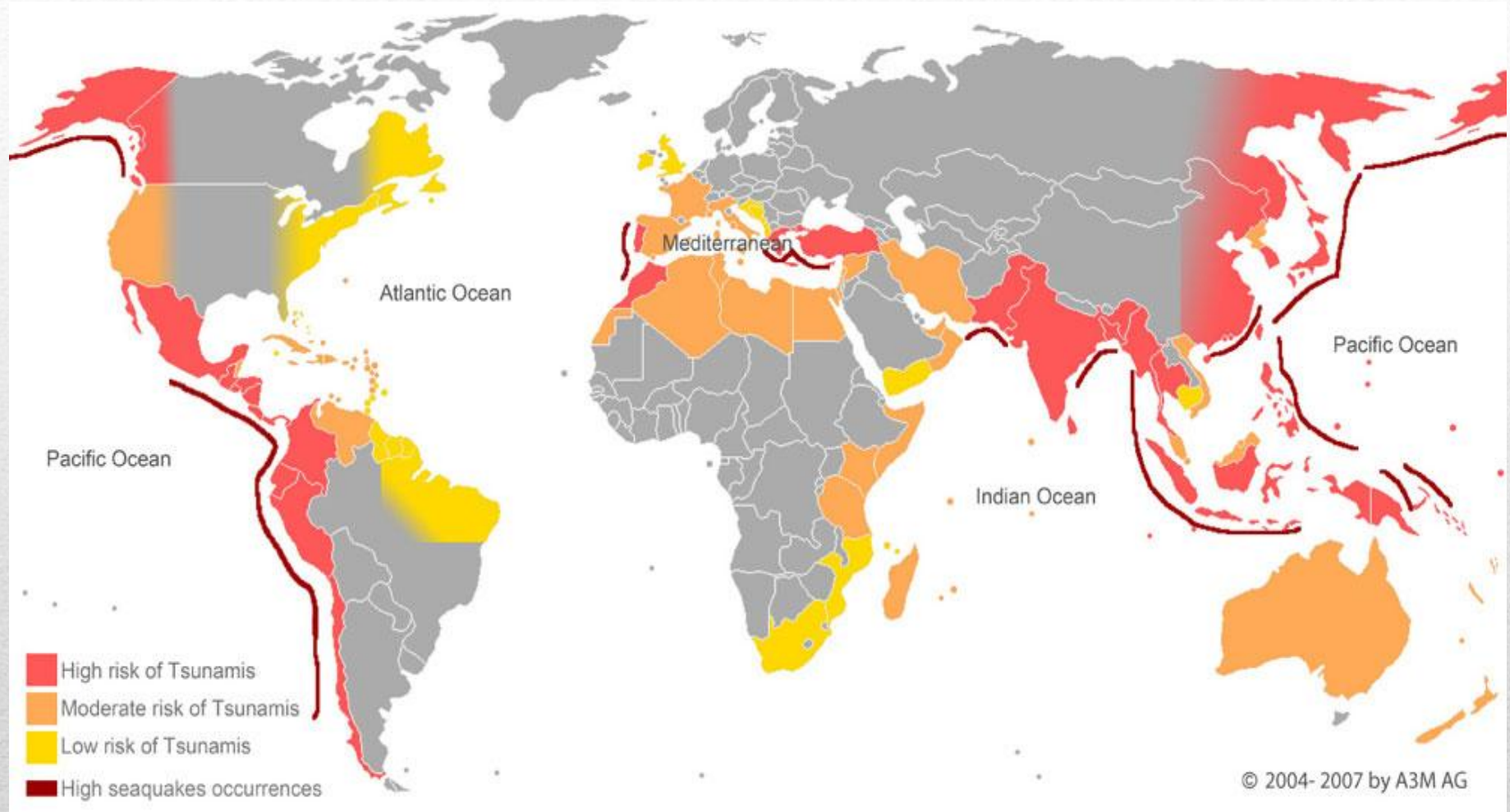
# Regions at Risk of Tsunamis

- Although all ocean and some lake shorelines are at risk for tsunamis, some are at a higher risk than others
  - This is caused by the geological location of the coast in relation to the potential tsunami sources such as earthquakes, landslides, and volcanoes.
  - Coastlines in close proximity to subduction zones are the greatest risk for tsunamis
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# Ranking the Tsunami Hazard Risk

- The ranking of tsunami hazard risks are ranked based on the return period of a significant tsunami – how high is the runup (how high is the wave)
  - A map of global tsunami hazards on coastlines shows that the highest hazards are along the subduction zones of the tectonic plates
  - On a map, the greatest, significant, and low hazard, these subduction zones are easily seen
  - The greatest hazard is around the Pacific Ocean, where there are not only tsunami hazards, but earthquake and volcano hazards
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# Effects of Tsunamis and Linkages with other Hazards

- Effects of tsunamis are primary and secondary
- The primary effect of a tsunami is the inundation of water and the resulting flooding and erosion
  - The wave energy is sufficient to tear up beaches and coastal vegetation as well as houses and buildings
  - This energy decreases as it goes inland farther, leaving behind destruction in its path as it retreats



# Effects of Tsunamis and Linkages with other Hazards

- The secondary effect of a tsunami occurs in the hours, days, and weeks after the event
    - Immediately after a tsunami,
      - Fires may start from broken natural gas lines and electrical lines
      - Water supplies can be polluted from the debris and flood waters left by the tsunami
      - Disease may breakout due to the polluted floodwaters, damaged wastewater treatment systems, and rotting animal carcasses
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# Effects of Tsunamis and Linkages with other Hazards

- There are several linkages with tsunamis and other hazards
  - Submarine and coastal earthquakes and landslides are three
  - Island volcanic explosions and oceanic impacts of asteroids and comets
  - Coastal earthquakes cause tsunamis waves which interact with the coastal process through erosion and deposition of sediment



# Natural Service of Tsunamis

- Large tsunamis are so destructive, it's hard to see any link to a service function or benefit
    - Tsunamis bring vast amounts of seawater over the land which can leave chemicals behind which could be beneficial to some ecosystems which have been deprived of nutrients
    - Tsunamis also bring large amounts of sediments onshore. Over time these sediments can fertilize the land they inundate, improving the land over time
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# Human Interaction with Tsunamis

- Humans cannot prevent or control tsunamis
  - Few if any tsunamis have been effected by humans
  - Nothing can be done to prevent to stop tsunamis
  - But there are some things we can do to lesson the damage
    - Buffer zones can be planted along the coast to absorb some of the impact of incoming tsunami waves
    - Buildings can also be reinforced in areas susceptible to tsunami flooding waves
    - These building can also be built further inland to avoid damage
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# Minimizing the Tsunami Hazard

- A number of strategies are available for minimizing the tsunami hazard. These are some:
    - Detection and Warning
    - Structural Control
    - Construction of tsunami runup maps
    - Probability analysis
    - Education
    - Tsunami-ready status
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# Minimizing the Tsunami Hazard

- **Detection and Warning**

- First warning come from the detection of giant offshore earthquakes
  - If the tsunami is in the open ocean, it can be detected and timed for its arrival onshore
  - A distant tsunami warning system has three components
    - A network of seismographs to locate and determine depth and magnitude
    - Automated tidal gauges to measure unusual rises and falls of sea level
    - A network of sensors connected to floating buoys
    - These would all work together to give a warning of a incoming tsunami
  - For local tsunamis there may be little time for a warning system
    - People would feel the ground move and quick move inland
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# Minimizing the Tsunami Hazard

- **Structural Control**

- Tsunamis even one or two meters high have the power to destroy houses or building
  - Building designs built to withstand the destructive power of tsunamis could greatly reduce the damage caused by the waves
  - Unfortunately, the building codes are taking a long time to change to reflect this structure designs

- **Tsunami Runup Maps**

- After a tsunami, it is relatively easy to produce a **tsunami runup map** showing where waves were encountered and how big they were
  - A community in a tsunami prone area can produce a hazard map showing areas where runup waves can happen
  - These maps could help a community lesson the damage if a tsunami should happen
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# Minimizing the Tsunami Hazard

- **Land Use**

- If the area has a tsunami hazard, using specific land use helps to limit damage from the waves
  - Planting large trees along coastal area helps to decrease the damage behind the trees
  - The trees will reduce the velocity of the incoming water
  - Land-use planning includes identifying where serious tsunami damage has or could occur can avoid damage in future tsunamis
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# Minimizing the Tsunami Hazard

- **Probability Analysis**

- The risk of a particular event happening can be “predicted” using mathematically probability calculations
  - To create this probability of a tsunami happening in an area there are certain things we have to look at
    - These are:
      - Identify and specify the potential earthquake sources and their associated uncertainties
      - Specify relationships that will either attenuate or reduce tsunami waves as they travel from the source area
      - Apply probabilistic analysis to the tsunami hazard similar to what is currently being done for earthquake hazard analysis.
        - Consider that tsunamis originate from multiple sources
        - This technique is the Monte Carlo simulation.
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# Minimizing the Tsunami Hazard

- **Education**

- Education concerning the tsunami hazard is **critical to minimizing risk**
  - Education people to listen for either a **tsunami watch** or a **tsunami warning**
  - People who know what to look for before a tsunami wave is coming have helped to save lives during huge tsunamis. This is natures warning system
  - People must also learn that tsunami wave have second and third waves. They need understand that so they stay on high ground
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# Minimizing the Tsunami Hazard

- **Tsunami-Ready Status**
    - Establish an emergency operation center with 24- hour capability
    - Have ways to receive tsunami warnings from the National Weather Service, Canadian Meteorological Centre, Coast Guard, or other agencies
    - Have ways to alert the public
    - Develop a tsunami preparedness plan with emergency drills
    - Promote a community awareness program to educate people concerning a tsunami hazard
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# Perception and Personal Adjustment to Tsunami Hazard

- Many people do not know the signs of an approaching tsunami or what to do if a watch or warning is issued
  - Personally if you are somewhere and you find a warning is issued take the following actions:
    - Although all earthquakes don't cause tsunamis, they can. If you feel an earthquake and you are on a beach area, head to high land
    - If the trough of a tsunami wave arrives first, the ocean will recede. This is a warning sign
    - Although a tsunami may be relatively small at one location, it may be much larger nearby
    - Tsunamis generally consist of a series of waves, and there can be up to an hour between waves
    - As coastal communities gain tsunami-readiness status, they will have warning sirens; if you hear a siren, move away from the beach to higher ground
    - If you are aware that a tsunami watch or warning has been issued, do not go down to the beach to watch the tsunami
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